FABRICATE AND INVESTIGATE THE PERFORMANCE OF THE FLOW-THROUGH SOLAR EVACUATED TUBE USING WATER-BASED NANOFLUIDS

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ABSTRACT

Experiments are undertaken to determine the efficiency of Evacuated Tube Collector (ETC) using water based Titanium Oxide ($Ti0_2$) nanofluid at Pekan campus (3˚30' N, 103˚ 25' E) Faculty of Mechanical Engineering, University Malaysia Pahang for conversion of solar thermal energy. These projects are carried out to fabricate the bracket for Evacuated Tube Collector (ETC), to determine the best parameter and to compare the efficiency of water and $Ti0_2$. Malaysia lies in the equatorial zone with an average daily solar insolation of more than 900W/m^2 and can reach a maximum of 1200 W/m^2 for most of the year. Nanofluids are liquids in which nanosize particles of metal or their oxides are dispersed in a base liquid such as water. It results in higher values of thermal conductivity compared to the base fluid. The increase in thermal conductivity with temperature is advantageous for applications in collectors, as the solar insolation varies throughout the day, with a minimum in the morning reaching a maximum at about 2pm and reducing thereafter. The fabrication of bracket was done by using two hydraulic car jacks. The best parameter for ETC is verified by flow rate for water is 2.7L/min and the tilt angle throughout the year is 8.2^0. The increment by temperature different in ETC is 23.46% maximum with 0.3vt% for 30-50nm size $Ti0_2$ nanoparticles dispersed in water, compared to the system working with water. However, the efficiency of solar ETC increased with increment in concentration from 0.3vt% and distilled water is 25.89% when the flow rate is fixed at 2.7 LPM. Thus, the nanofluids is capable to absorb solar thermal energy at all available solar insolations in the present experiment.

ABSTRAK

Eksperimen yang dijalankan untuk menentukan kecekapan pemungut tiub yang dipindahkan (ETC) dengan menggunakan air berdasarkan Titanium Oksida (Ti02) nanofluid di Pekan kampus (3 ˚ 30 'N, 103 ˚ 25' E) Fakulti Kejuruteraan Mekanikal, Universiti Malaysia Pahang untuk penukarantenaga terma suria. Projek-projek ini dijalankan untuk memalsukan kurungan untuk pemungut tiub dipindahkan (ETC), untuk menentukan parameter yang terbaik dan untuk membandingkan kecekapan air dan Ti02. Malaysia terletak di zon khatulistiwa dengan purata harian sinaran matahari lebih daripada 900W/m2 dan boleh mencapai maksimum sebanyak 1200 W/m2 bagi kebanyakan tahun. Nanofluids adalah cecair di mana partikel saiz nano oksida logam atau mereka yang disebarkan dalam cecair asas seperti air. Ia menyebabkan nilai-nilai yang lebih tinggi kekonduksian terma berbanding dengan bendalir asas. Peningkatan dalam kekonduksian terma dengan suhu berfaedah bagi permohonan dalam pengumpul, sebagai sinaran matahari berubah-ubah sepanjang hari, dengan sekurang-kurangnya pada waktu pagi mencapai maksimum pada kira-kira 2 petang dan penurunan selepas itu. Fabrikasi pendakap telah dilakukan dengan menggunakan dua bicu hidraulik kereta. Parameter terbaik untuk ETC disahkan oleh kadar aliran air adalah 2.7L/min dan sudut kecondongan sepanjang tahun adalah 8.2^0. Kenaikan perbezaan suhu dalam ETC adalah maksimum 23.46% dengan 0.3vt% untuk 30-50nm saiz Ti02 nanopartikel yang berselerak di dalam air, berbanding dengan sistem yang bekerja dengan air. Walau bagaimanapun, kecekapan ETC meningkat dengan kenaikan tumpuan dari 0.3vt% dan air suling adalah 25.89% apabila kadar aliran ditetapkan pada kadar 2.7L/min. Oleh itu, nanofluids mampu untuk menyerap tenaga haba suria di semua sinaran matahari dalam eksperimen ini.

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LIST OF SYMBOLS

η	Efficiency of the system
η_o	Correlation Coefficient
T_a	Ambient temperature, ^oC
T_m	Mean temperature, ^oC
T_{out}	Outlet temperature, ^oC
T_{in}	Inlet temperature,^oC
G_T	Global solar radiation, W/m^2
A_c	Surface area of collector, m^2
$\dot{m}$	Mass flow rate, kg/s
Q_u	Heat rate, W
$C_{p,w}$	Specific heat of water at constant pressure, J/kg.^oC
ρ_w	Density of water, kg/m^3
ρ_p	Density of nanoparticle, kg/m^3
ϕ	Volume concentration of nanoparticle in volume percent
φ	Volume concentration of nanoparticle in weight percent
ρ_w	Density of water, kg/m^3
m_p	Mass of nanoparticle, g
m_w	Mass of water,g
n	Leap year/ Non leap year + Day
β	Angle made by the plane surface with the horizontal
I_{sc}	Solar constant
δ	Declination angle
ω_{st}	Hour angle

N_{MAX}	Monthly average of maximum possible sunshine hours per day, in hours
$\overline{H}_o$	Monthly average of daily extraterrestrial radiation on a horizontal surface, kJ/m^2.day
$\overline{H}_g$	Monthly average of daily global radiation on a horizontal surface, kJ/m^2.day
a, b	Regression coefficients which vary from site to site
$\overline{H}_d$	Monthly diffuse radiation, kJ/m^2.day
$\overline{H}_b$	Monthly beam radiation, kJ/m^2.day
β_{opt}	Optimum angle
I_c	Solar radiation at collector, W/m^2
Cp_{nf}	Nanofluids specific heat energy, J/kg.K
Cp_p	Nanoparticle specific heat energy, J/kg.K

LIST OF ABBREVIATIONS

ETSC	Evacuated Tube Solar Collector
SRCC	Solar Rating and Certification Corporation
UMP	Universiti Malaysia Pahang
RE	Renewable Energy
TNB	Tenaga Nasional Berhad
IPP	Independent Power Producers
ETC	Evacuated Tube Collector
SWH	Solar Water Heater
Al_2O_3	Aluminium Oxide / Alumina
EG	Ethylene Glycol
EO	Engine Oil
CuO	Cuprum Oxide
SiO_2	Silicon Oxide / Silica
SEM	Scanning Electron Microscope
TiO_2	Titanium Oxide / Titania
PV	Photovoltaic
FKM	Fakulti Kejuruteraan Mekanikal

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The greatest potential of all sources of renewable energy is solar energy especially when other sources in the country have depleted. There are so many methods that have introduced to increase the efficiency of the solar water heater. Solar Energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The principle involve in collecting solar energy is rather simple depending on the receiving surfaces which are able to absorb as much as possible of the incoming solar flux. The ability to retain heat is a condition and transferred through tubes by working fluids. There are many types of solar collector such as flat plate, evacuated tube and heat pipe. In this project will concern about the flow through evacuated tube solar collector.

However, the novel approaches to introduce the nanofluids in solar water heater instead of conventional heat transfer fluids. The poor heat transfer properties of these conventional fluids compared to most solids are the primary obstacles to high compactness and effectiveness in the system. The essential initiative is to seek the solid particles having thermal conductivity of several hundred times higher than those of conventional fluids. An innovative idea is to suspend ultrafine solid particles in the fluid for improving the thermal conductivity of the fluid.

1.2 PROBLEM STATEMENT

Nowadays, some building in Malaysia are using on solar water heater system, and the main reason is to energy saving in hot water technologies. The current problems faced by solar water heater are;

1. The material cost for build solar technology is the biggest problem. The material such as evacuated tube solar collectors is still very expensive. Therefore, this project will reduce the payback period of building solar collector.

2. Another major problem to have a solar energy as renewable energy is that every location on Earth does have the same direct sunlight. Most of the areas in this world only can used a low-power solar energy because of cloud cover that limits the availability of solar energy.

3. Certain types of solar water heating system cannot function when on cloudy time and need a backup water heating system to ensure the hot water available all the times. This system cannot be used in freezing temperatures in the country that have winter season. However, Malaysia can prevent this problem because of the weather in Malaysia is good enough to make the solar collector the best efficient.

4. There are two methods to prepare the nanofluids. However, many of researchers are still in research to find the best way of preparing the nanofluids. Many of them are working with the problem on stability of nanofluids that have the sedimentation in the nanofluids.

1.3 OBJECTIVES

The objectives are:

1. To fabricate the bracket for Evacuated Tube Solar Collector (ETSC) and the systems.
2. To develop an efficient water-based nanofluid solar collector by optimizing the flow rate and collector tilt angle that applicable to Pekan.
3. To compare the efficiency of water and water-based nanofluid flow through evacuated tube solar collector.

1.4 SCOPE OF PROJECT

The scopes are:

1. Equipments:
    a. Flow Through Evacuated Tube Solar Collector
    Model: SEIDO 2-16
    Feature: One of the highest performing Solar Rating and Certification Corporation (SRCC) rated thermal collectors. The collector can be oriented in any manner. The absorption coefficient is more than 92% by using Aluminium Nitride coating.
    b. The solar flow through evacuated tube data was collected manually with the interval 15minutes.
2. The location of the experiment will be in Universiti Malaysia Pahang (UMP), Pekan.
3. Calculation will be instantaneous efficiency.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This literature review explores about four major scopes in this report which are renewable energy, solar energy, evacuated tube solar collector and nanofluids. The literature review provides a background to the study being proposed. The background may consider previous findings, rational of the relevant study, methodology or research methods, and theoretical background. Most of the literature reviews have been extracted from journals, books and web site. This is important because we can avoid the same mistakes done by the previous study. However, with these literature reviews, the project can be run smoothly.

2.2 RENEWABLE ENERGY

The word energy is derived from the Greek en (in) and *ergon* (work). There are many forms of energy which are heat, work, chemical energy in forms of fuels or batteries, kinetic energy which in moving substances, electrical energy, gravitational energy and potential energy by virtue of its elevation. Energy can divide into two major of energy. There are alternative energy that refers to any source of usable energy intended to replace fuel sources without the undesired consequences of the replaced fuels; and renewable energy that refers to energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which is naturally replenished.

2.2.1 World Energy Scenario

World Primary Energy Consumption 2011

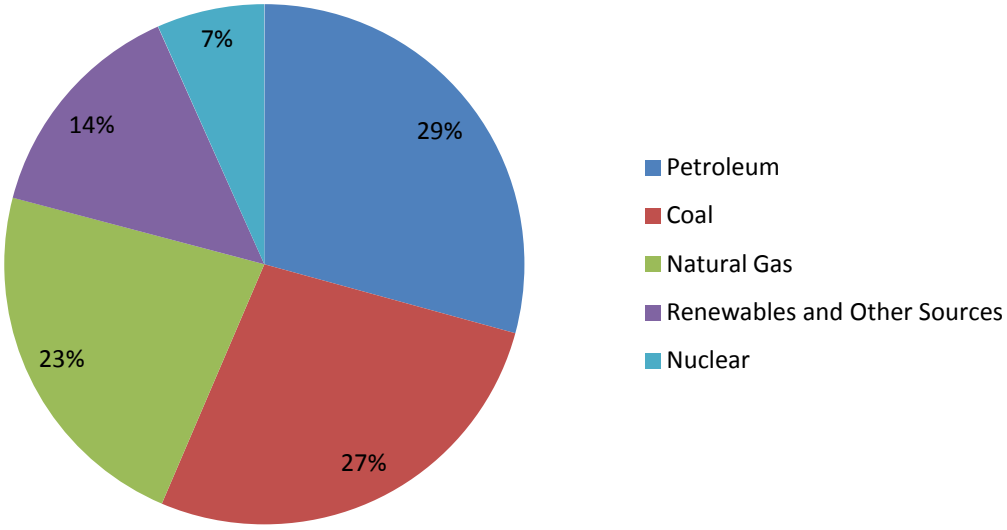

Figure 2.1: World's energy scenario

[Source: (Bredenberg May 7th, 2012)]

Mostly, world primary energy consumption is based on energy that already has but mainly of this energy can be depleted. Renewable energy contributes 14% energy to the world. Therefore, we should increase the usage of renewable energy. The bad effects on environment caused by the production and consumption of energy have resulted in harsh environmental impacts across the globe. The supply of energy is expected to remain as much as necessary in coming years. However, imbalance of energy consumption is common around the world. Energy consumption is high in most developed countries. On the other hand, the developing countries need to consume more energy to ensure economic growth. The economic development of many countries is caught up due to "energy poverty".(EconomyWatch 30 April 2010)

The major sources of energy in the world are oil, coal, natural gas, hydro energy, nuclear energy, renewable combustible wastes and other energy sources. Combustible wastes include animal products, biomass and industrial wastes. Renewable energy will be more concentrate in this project because to helps and decrease the usage of available energy.

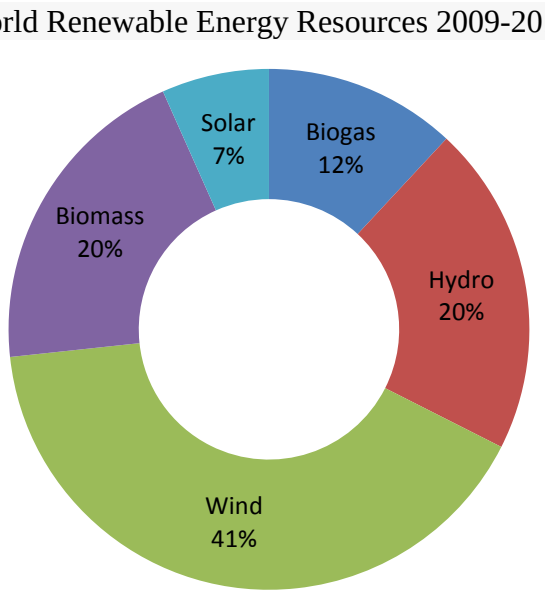

Figure 2.2: World's energy scenario in renewable energy sources

[Source: (Gabor 2011)]

Figure 2.2 shows the renewable energy scenario in this world. Traditional Biomass gives the big amount of energy resources to provide energy to peoples. Tidal energy is the lowest application in renewable energy. There are many initiatives to educate the peoples in this world about the important of renewable energy.

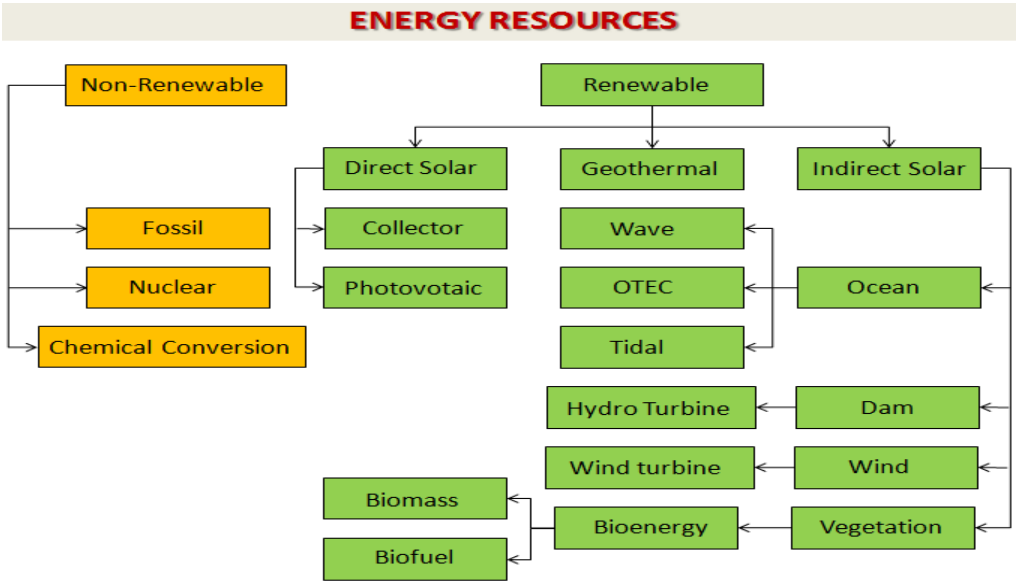

Figure 2.3: Energy Resources

[Source: (Frank Kreith 1942)]

The energy resources are divided into two major parts which are non-renewable and renewable energy. Under the renewable energy, there are many types of energy that provide energy to our needs. However, this project is about the solar energy.

Renewable energy can be particularly suitable for developing countries. In rural and remote areas, transmission and distribution of energy generated from fossil fuels can be difficult and expensive. Producing renewable energy locally can offer a viable alternative. Renewable energy projects in many developing countries have demonstrated that renewable energy can directly contribute to poverty elimination by providing the energy needed for creating businesses and employment. Renewable energy technologies can also make indirect contributions to elimination poverty by providing energy for cooking, space heating, and lighting. Renewable energy can also contribute to education, by providing electricity to schools.

2.2.2 Energy Resources in Malaysia

2.2.2.1 Generation Fuel Options

The New Five-Fuel Diversification Strategy replaces the Four-Fuel Diversification Strategy, in which the fifth fuel under the New Strategy is non-hydro renewable energy (RE) alongside the existing four fuels utilised for power generation, namely, oil, gas, coal and hydro. The Four-Fuel Strategy and subsequently the New Five-Fuel Strategy has been successful in bringing down oil consumption for power generation from more than 80% in the 1980's to about 32% in 1998 and further down to about 4% in 2000. The Government is also looking into efficient energy utilisation and consumption through the National Energy Efficiency Strategy. There are therefore no firm plans at present for the introduction of nuclear power generation, although Tenaga Nasional Berhad (TNB) maintains an interest in nuclear power technology through a continuing programme of technical and manpower training. TNB has the largest generation capacity of over 7,500 MW that accounts for over 62% of the total power generation of Peninsular Malaysia.

2.2.2.2 Oil

In the early eighties, oil-fired generation contributes to a substantial proportion of TNB's output and operating costs were significantly affected by excursions in oil prices since late 1973. Despite current low prices of fuel oil, oil-fired generating plants are not considered to be strongly competitive options for long term planning purposes, in view of the uncertainties of future prices, and other available alternatives. In TNB, oil requirement has reduced over the years.

2.2.2.3 Natural Gas

Natural gas has become an important fuel for gas turbines and combined-cycle plant developments, both for TNB and IPPs. The Phase II of the Peninsular Gas Utilisation Pipeline Project has made available natural gas to the West Coast and South of Peninsular Malaysia in the late 1991.

With the completion of the gas pipeline project and the advent of Independent Power Producers (IPP) in 1994, gas utilisation in power generation has increased tremendously. To-date, gas contributed to about 76% of the total generation capacity mix.

2.2.2.4 Coal

Coal is also commercially available from foreign sources and this fuel is an option for our power generation development studies. Current indications are that imported coal will be a competitive fuel source for electric power generation in Malaysia. The third phase Port Klang Power Station, which was scheduled to be commissioned in 2001, comprises two 500 MW coal-fired units capable of burning coal or gas or oil. In addition, the Janamanjung Power Station which is a 2,100 MW coal-fired plant is expected to come online in year 2003. More coal-fired plants (including IPPs) have been proposed in the years beyond 2000 for security of power supply and to conform to the diversification of fuel usage in power sector as required by the national fuel policy. Currently coal-fired generation constitutes about 5% of the total generation capacity mix.

2.2.2.5 Hydroelectricity

It is estimated that the indicative hydro potential in Peninsular Malaysia totals some 16 TWh/year. Nine major hydro stations with a capacity of 1,874 MW are currently in service. This total capacity includes the recently commissioned Pergau Hydroelectric Station (in 1997) which contributes a total peaking capacity of 600MW. Three other hydroelectric projects have been identified and under planning stage namely, Ulu Terengganu (300MW), upgrading of Kenyir Hydro station (300MW) and Ulu Jelai's mixed pumped storage (1,000MW- 1,200MW) with 300MW conventional hydro scheme.

2.2.2.6 Renewable Energy

Renewable energy (RE) has been identified and finalised by the Government as the fifth fuel under the New Five-Fuel Diversification Strategy. The RE focus would be on biomass, especially from palm oil and wood wastes. The target of contribution towards the total electricity generation mix from RE is 5% by 2005 and 10% by 2010, after which this ratio could be maintained thereafter.

2.3 SOLAR ENERGY

An incredible supply of solar energy has received by the earth. An average star, the sun is a fusion reactor that has been burning over 4 billion years. In fact, “The amount of solar radiation striking the earth over a three-day period is equivalent to the energy stored in all fossil energy sources.” Sun provides energy in one minute to supply the world’s energy needs for one year. In one day, sun can provides more energy than our current population would consume in 27 years. It means, the sun can deliver 7000 times more energy to the Earth’s surface. Earth receives approximately 170 million GW of power from the sun, which is a relatively tiny fraction of the sun’s total output, but is millions of times greater than the maximum power demand of Earth’s entire population. The Earth distance from the sun is 149,596,000 km, therefore, the solar flux relatively small. About 1369 watts per square meter (W/m^2) is the intensity of the solar radiation that reaches us and this values also known as Solar Constant. To put it another way,

solar energy captured by the Earth over a period of 1000 years is equal to the energy produced by the Sun in just only 14 seconds.

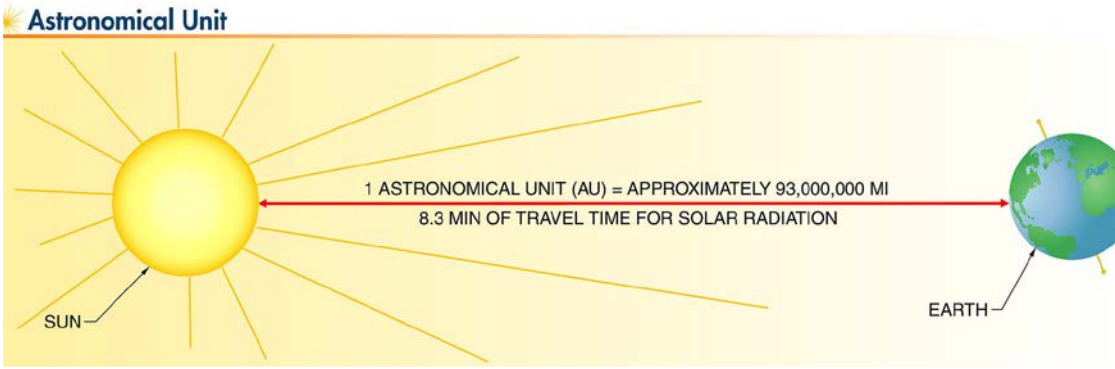

Figure 2.4: Properties of Solar Radiation

[Source: (D. Yogi Goswami 2000)]

The information on sunshine hour, solar radiation intensity and daily variation of global solar radiation are one of the important aspects to design a suitable solar system for a particular application such as photovoltaic water pumping system, solar thermal and drying system. In tropical countries like Malaysia, the cloud pattern can be highly variable due to high humidity and unpredictable weather, especially during the monsoon seasons. Mainland Malaysia is a peninsula lying between latitudes 1.30 and 6.60^0N, and longitudes 99.50 and 103.30^0E. As in many places at Malaysia is mainly influenced by the system of the Asian monsoons. (Mohd Yusof Hj. Othman 1992)

Some observers has observed at Malaysia that instantaneous solar radiation intensity sometimes rises higher than solar constant, even reaching 1.4 kW/m^2 which is the saturation point of the recording system. For such a clear day, the maximum instantaneous solar intensity was 971 W/m^2 and the amount of solar energy received during the whole day was 6.957kWhr/m^2. For the whole day, about 12hours Malaysia will receive the amount of solar energy which is from 7 a.m. until 7 p.m. The comparison of lower value than desert area is because the atmosphere in Malaysia is denser than desert due to the higher humidity. Besides that, for fully cloudy day, the maximum solar intensity received was 121.4 W/m^2 and for the whole day was 0.5kWhr/m^2. For partly cloudy day, the maximum solar intensity can get around 1142.9 W/m^2 and total solar radiation was 4.43kWhr/m^2.(Mohd Yusof Hj. Othman 1992)

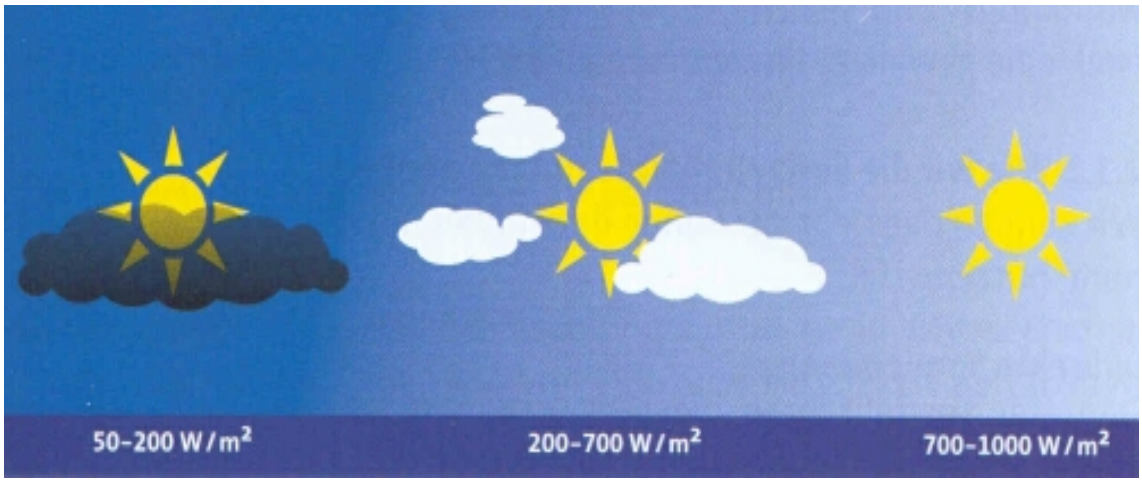

Figure 2.5: Irradiation under different weather conditions

[Source: (SP Sukhatme 2009)]

Furthermore, the global solar radiation pattern with instantaneous intensity higher than solar constant was record 1400 W/m^2 which the maximum intensity that recorded and the total amount solar radiation on that day can achieve 4.16kWhr/m^2. The difference in units by using W/m^2 and kWhr/m^2 are for W/m^2, are taking from the reading. However, for kWhr/m^2 is the total of solar radiation times by the sun received for the whole day. Other than that, when it's rainy in the afternoon, the maximum instantaneous solar intensity was 957 W/m^2 and total solar radiation received for the day was 3.00kWhr/m^2.(Mohd Yusof Hj. Othman 1992). Due to this consideration, the specifications and components solar system can be determine for installation in Malaysia and similar locations.

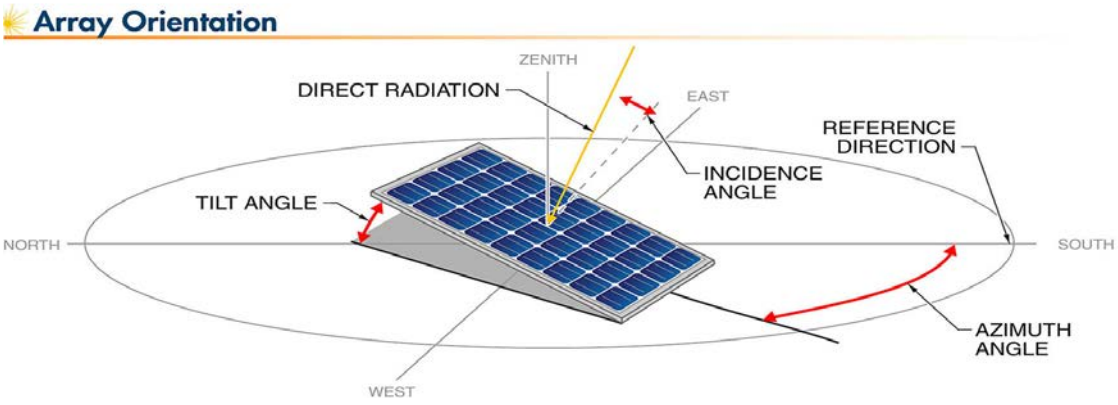

Figure 2.6: Array orientation can be described using azimuth or tilt angles for installation solar system

[Source: (John A. Duffie 2006)]